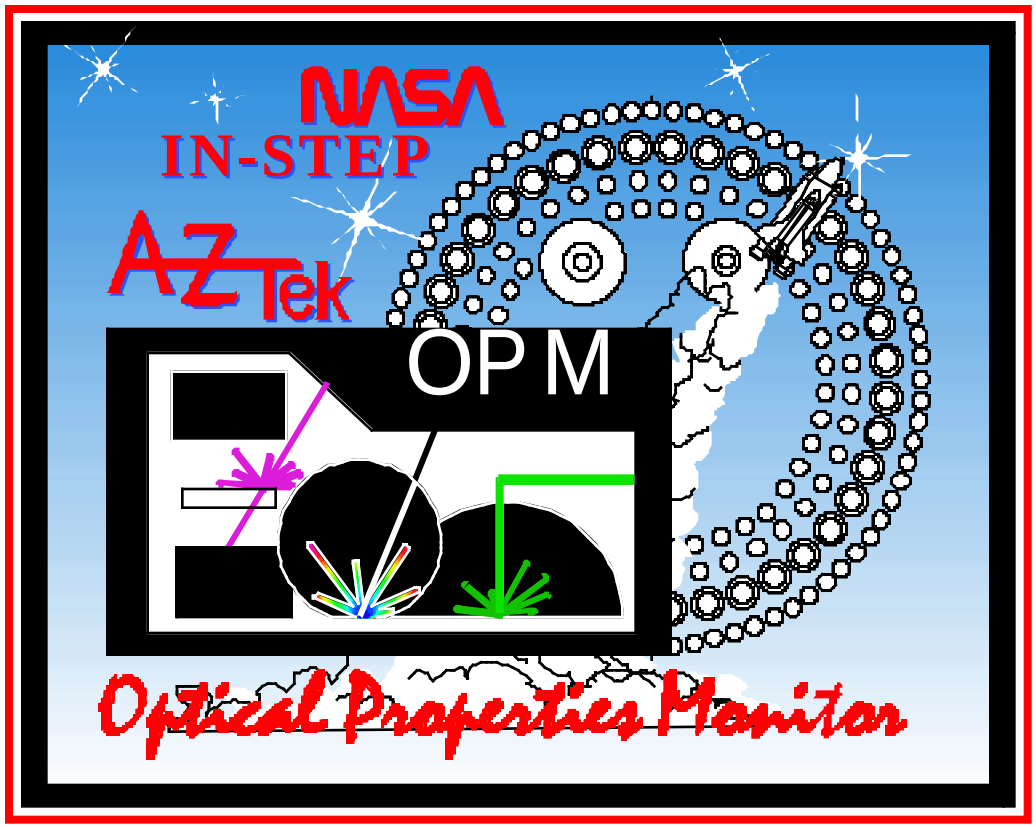
AZ TECHNOLOGY

OPTICAL PROPERTIES MONITOR (OPM)
SEE Flight Experiments Workshop
June 24, 1998



AZ TECHNOLOGY

OPTICAL PROPERTIES MONITOR (OPM)
SEE Flight Experiments Workshop
June 24, 1998

Principal Investigator	D.R. Wilkes, AZ Technology
Project Scientist	J.M. Zwiener, NASA/MSFC
Project Manager	S.R. Davis, NASA/MSFC
Co-Investigators	J.M. Bennett E.R. Miller
Science Team	J.B. Hadaway, UAH Center for Applied Optics R.R. Kamenetzky, NASA/MSFC J.C. Gregory, UAH J.S. Harchanko D. Crandall R.M. Mell Many Others
Sponsors	Dr. D. Brewer, Crosscutting Technology Program, Office of Space Science R. Lofton, ISS Phase I Program

OPM Experiment Objectives

To study the effects of the Mir space environment, both natural and induced, on optical, thermal control, solar array, and other materials.

- Determine the effects and damage mechanisms of the Mir space environment on materials.
- Provide data to validate lifetime prediction models.
- Perform flight testing of critical spacecraft and instrument materials.
- Provide data to validate space simulation test facilities and techniques.
- Develop a reusable multifunctional flight instrument for optical studies.

Experiment Overview

The OPM is a multifunctional, reusable in-flight laboratory for the in-situ study of materials. Selected materials were exposed to the low earth orbit space and Mir induced environment and their effects measured through in-situ measurements and post-flight analyses.

- Optical and thermal properties are measured by in-situ measurement subsystems.
  - Spectral total hemispherical reflectance
  - Total Integrated Scatter (TIS)
  - Vacuum Ultraviolet (VUV) reflectance/transmittance
  - Total emittance

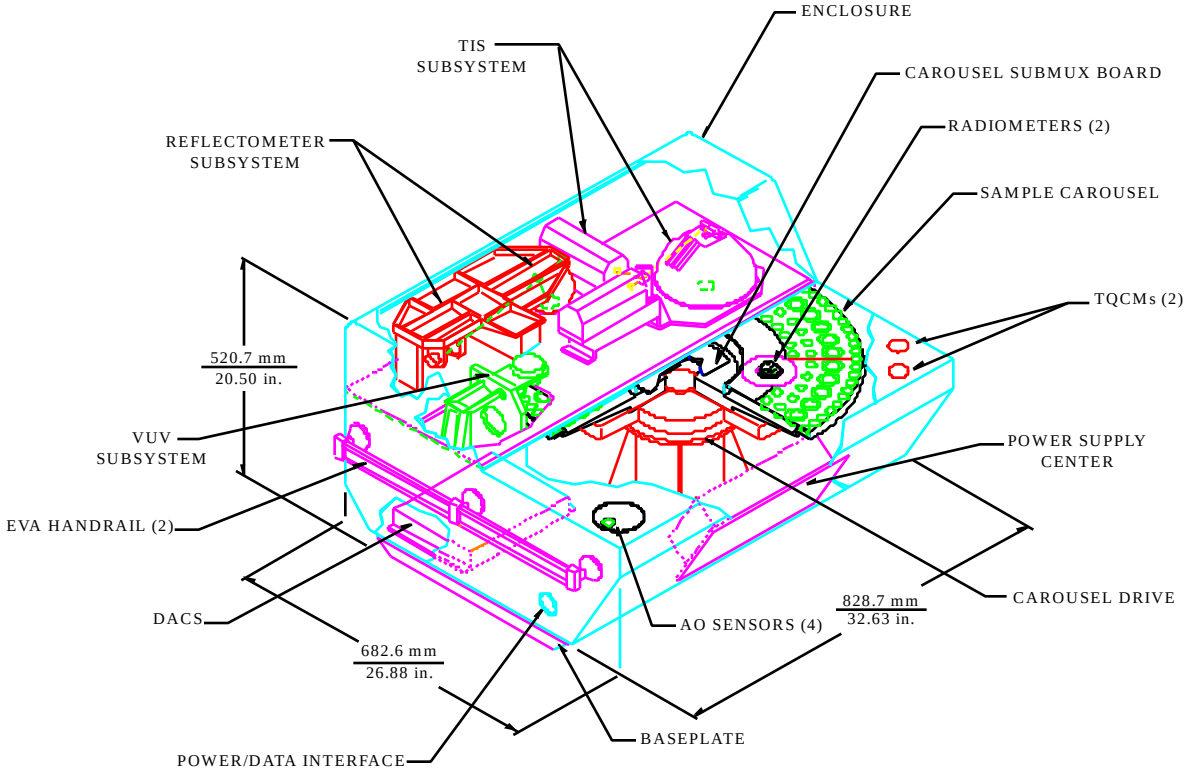
- Environmental monitors measure selected components of the exposure environment.
  - Solar/earth irradiance
  - Molecular contamination
  - Atomic oxygen

- Detailed optical and thermal properties, surface degradation, and contamination are determined by post-flight analyses.

AZ TECHNOLOGY

OPTICAL PROPERTIES MONITOR (OPM)
SEE Flight Experiments Workshop
June 24, 1998

OPM Assembly



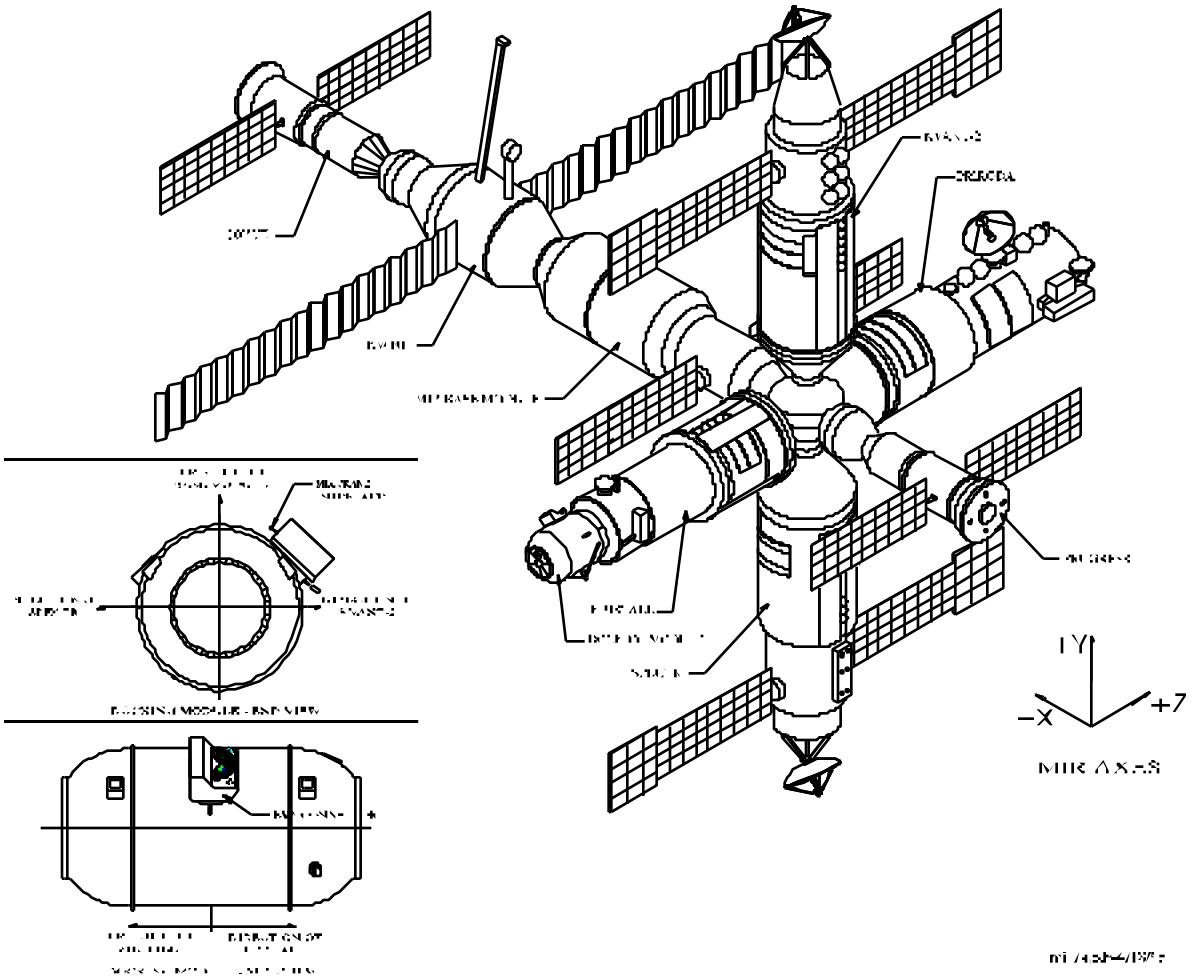
assycolr.cdr - 4/18/96

NOTE: DIMENSIONS INCLUDE MLI

AZ TECHNOLOGY

OPTICAL PROPERTIES MONITOR (OPM)
SEE Flight Experiments Workshop
June 24, 1998

OPM Mir Mounting on Docking Module



OPM Mission Description

- Carried to Mir in SpaceHab on STS-81 (January 1997)
- Deployed on the exterior of the Mir Docking Module (DM)
  - Joint US/Russian EVA
  - Powered up at 02:21 CDT (07:21 GMT) on April 29, 1997
- OPM operated until January 8, 1998
  - Power off from 6/25/97 to ~9/9/97
  - Other power outages after 9/9/97
  - Environment monitoring
  - Weekly optical properties measurements
  - Data downlinked through MIPS system
- OPM retrieved from DM on 1/9/98 (MT) by Russian EVA
- OPM returned to ground on STS-89 in late January, 1998

Status Summary

- Activities Performed
  - In-flight data has been reduced and processed.
  - The OPM has been returned to the lab for continued analyses.
  - Post-flight measurement have been performed on flight samples with the OPM instruments.
  - Post-flight analysis of flight and control materials is underway.

- Hardware Performance
  - Most OPM instruments and subsystems performed very well over the Mir mission providing unique data on the behavior of materials in the Mir environment.

- Anomalies - Three anomalies occurred during the OPM mission on Mir:
  - The VUV spectrometer lamp did not function during the mission.
  - The solar radiometer ceased to operate during the full sun Mir orbit in early June.
  - The reflectometer tungsten lamp failed during the final in-space measurement cycle.

Test Sample Exposure Environment

Environment	4/29 to 6/30 Total*	Mission Total
Exposure Duration	63 days	237 days
Solar irradiance	106 ESH	500 ESH (Est.)
AO fluence	1.8×10^{19} atoms/cm^2	7×10^{19} atoms/cm^2 (Est.)

*From attitude data provided by RSC-E.

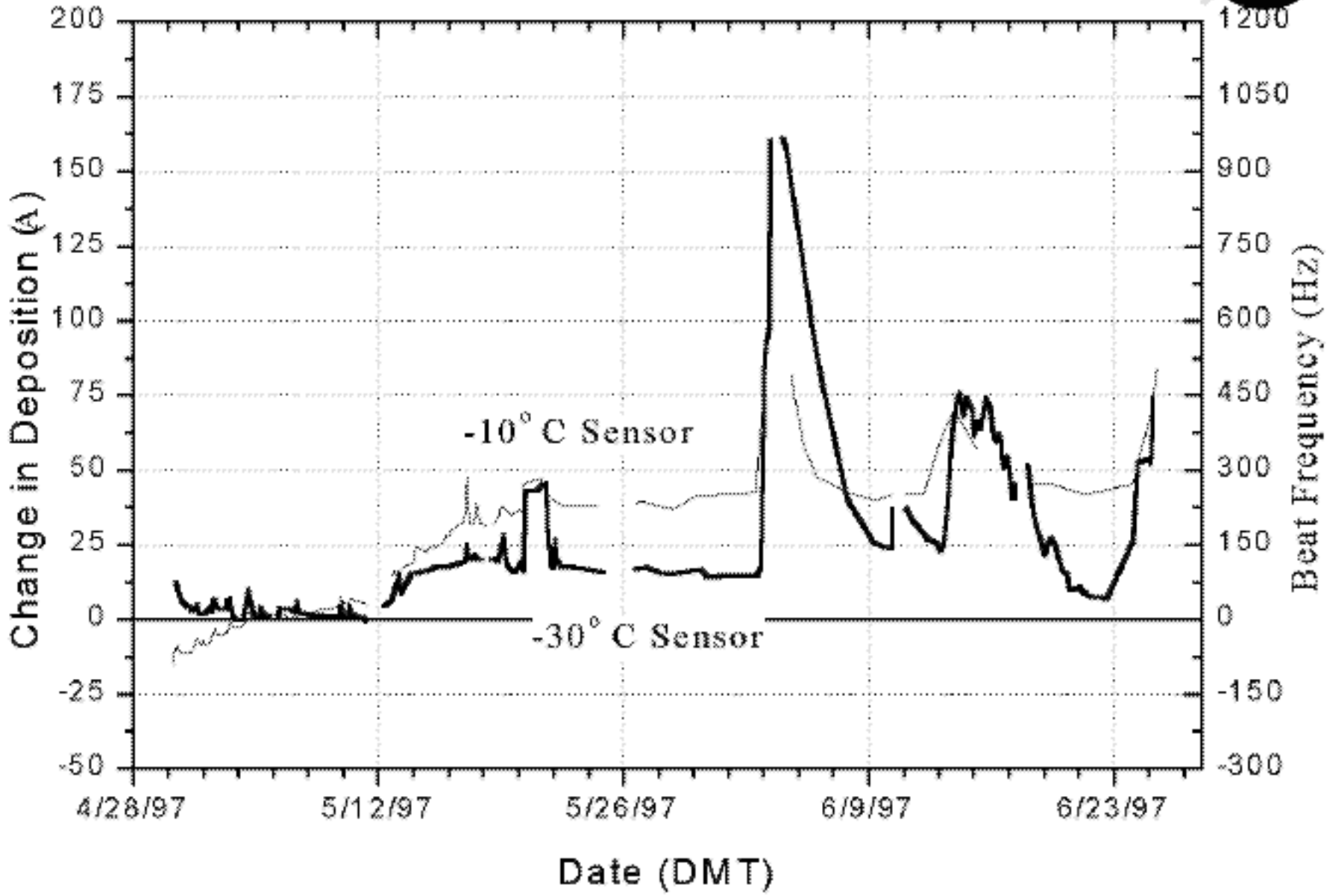
TQCM Molecular Contamination Monitors

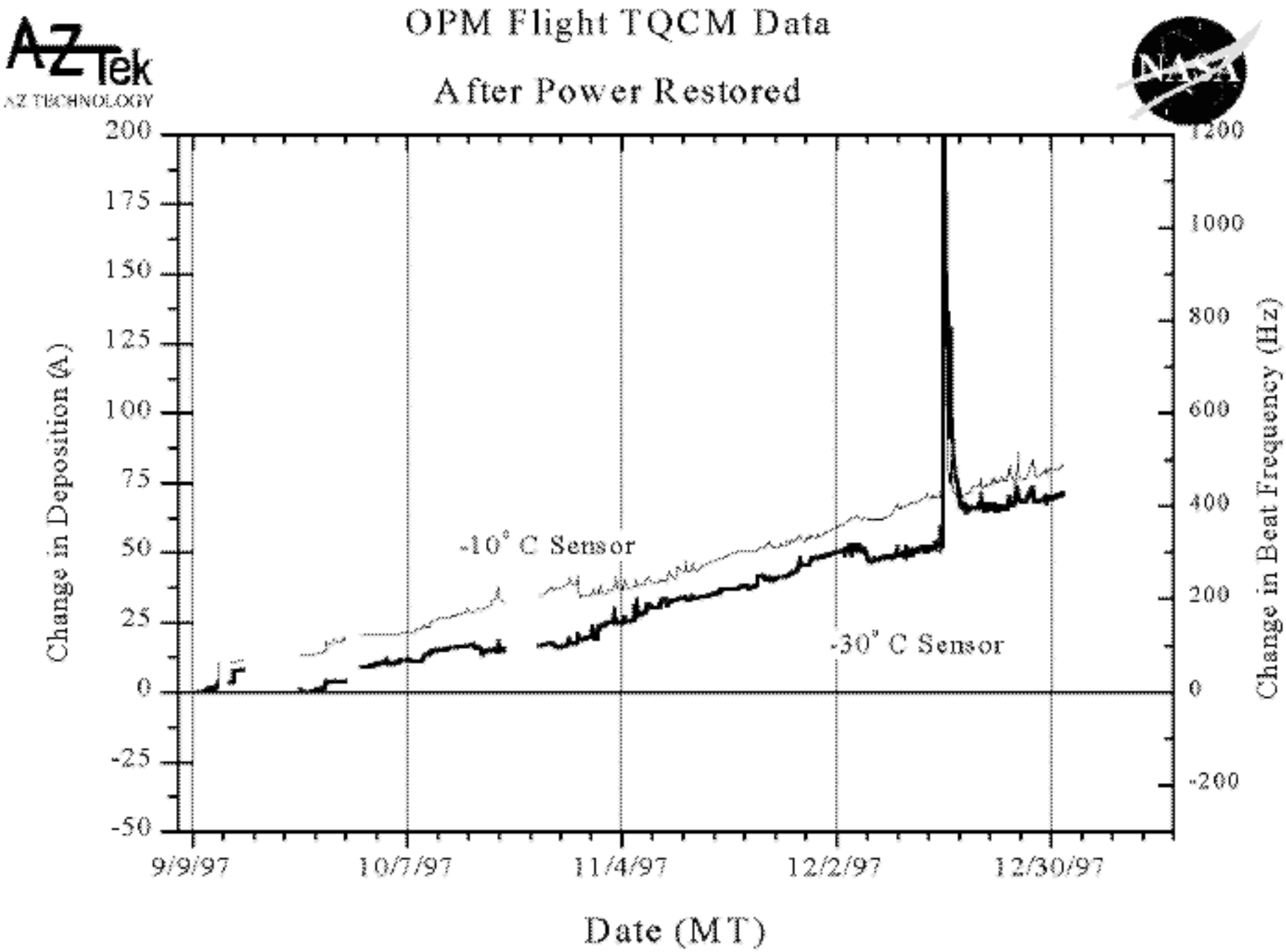
- Temperature-controlled Quartz Crystal Microbalance (TQCM) is used to measure mass deposited onto the sensor.
- Sensitivity is 1.6 x 10 g/cm /Hz.
- Two TQCM sensors are on OPM. One sensor operates at -30 C and the other at -10 C.
- Temperature and beat frequency for each sensor is recorded at 1 minute intervals except when optical measurements are being performed.

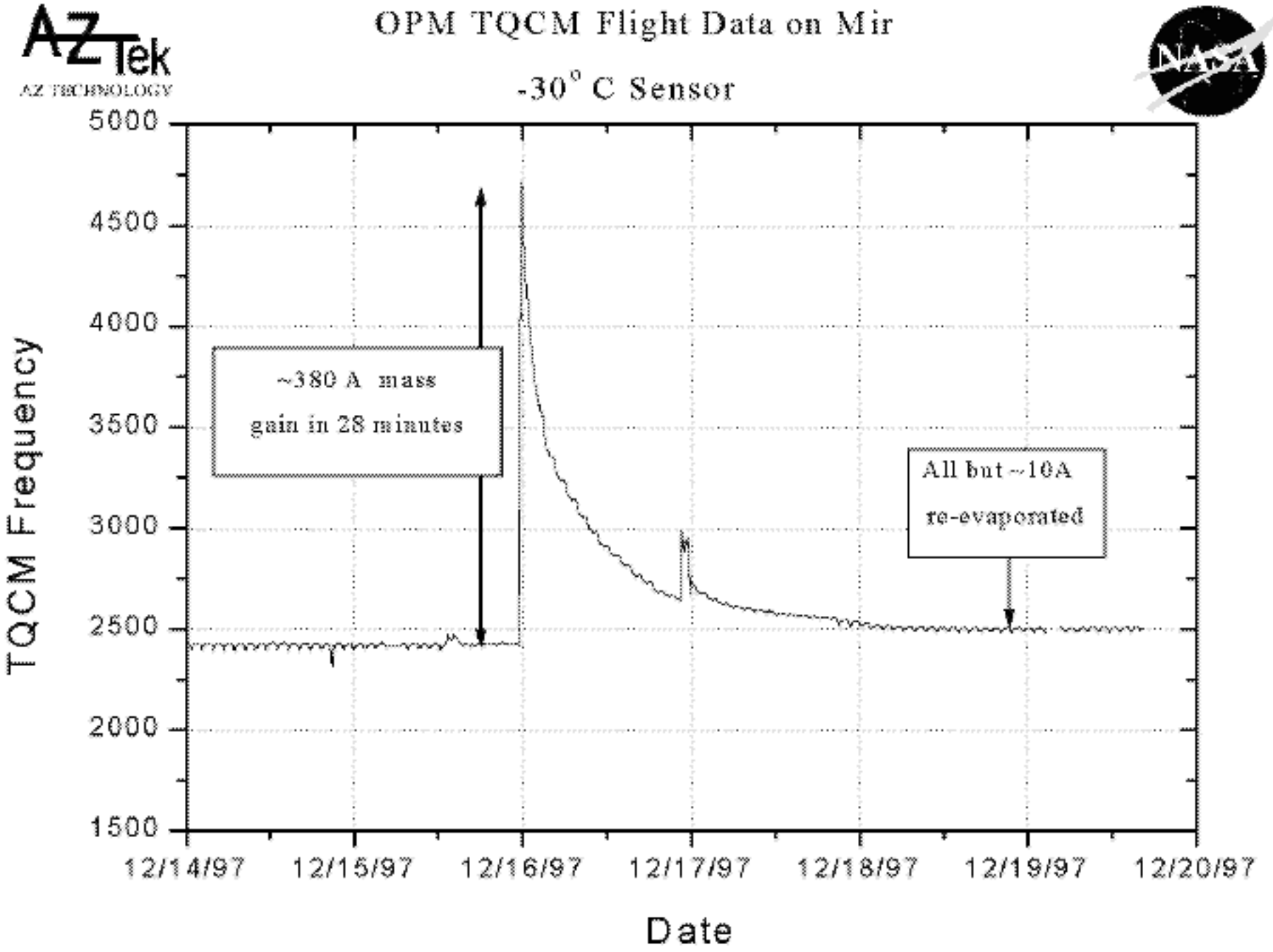
AZ Tek
AZ TECHNOLOGY

OPM Flight TQCM Data

Before Progress Accident

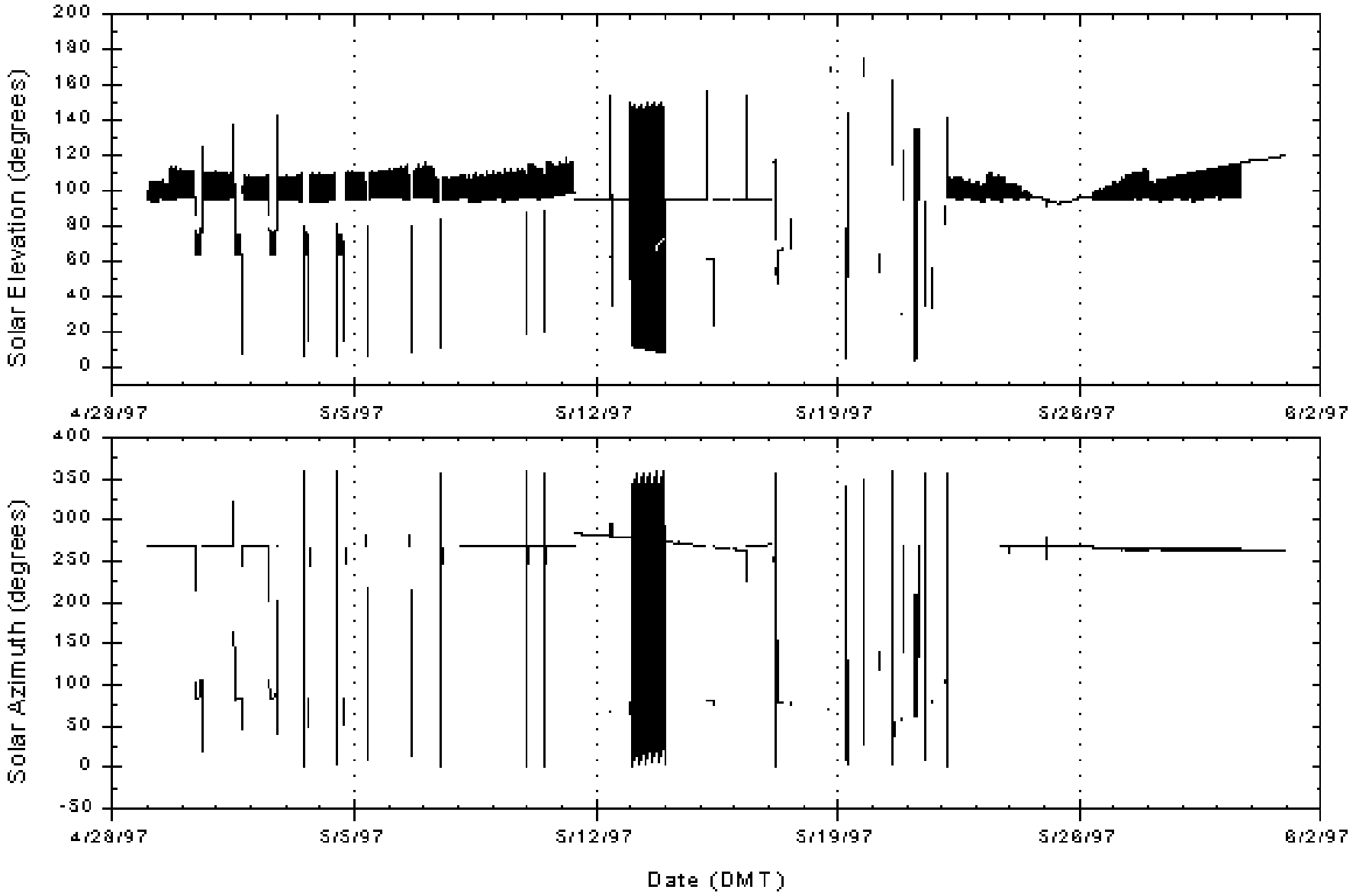



AZTek
AZ TECHNOLOGY
OPM Flight TQCM Data
After Power Restored
-10° C Sensor
-30° C Sensor
Change in Deposition (A)
Change in Beat Frequency (Hz)
200
175
150
125
100
75
50
25
0
-25
-50
1200
1000
800
600
400
200
0
-200
9/9/97
10/7/97
11/4/97
12/2/97
12/30/97
Date (MT)


AZTek
AZ TECHNOLOGY
OPM TQCM Flight Data on Mir
-30° C Sensor
NASA
TQCM Frequency
5000
4500
4000
3500
3000
2500
2000
1500
~380 A mass
gain in 28 minutes
All but ~10A
re-evaporated
12/14/97
12/15/97
12/16/97
12/17/97
12/18/97
12/19/97
12/20/97
Date

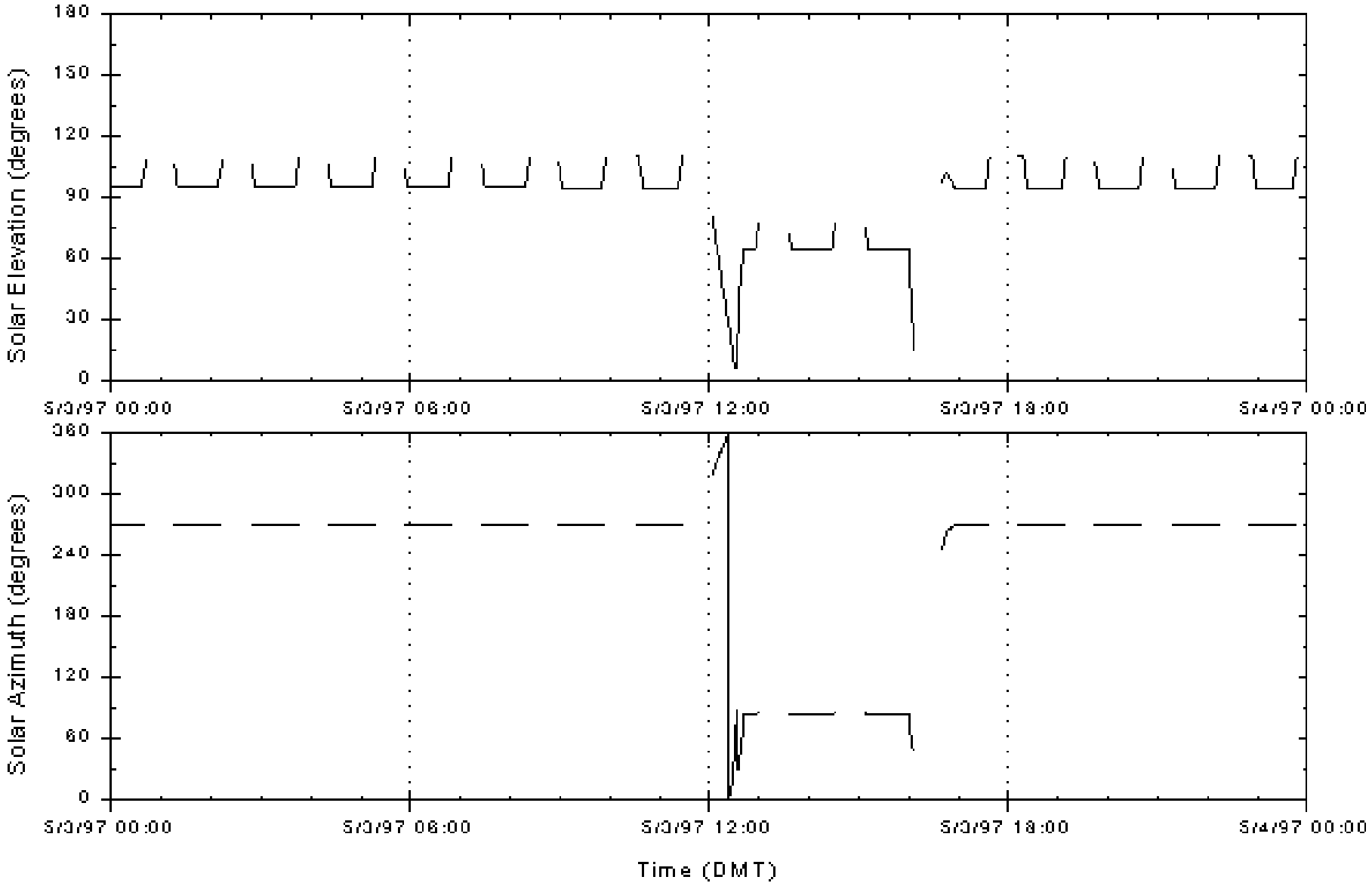
AZTek
AZ TECHNOLOGY

OPM/Mir Attitude Data for May, 1997

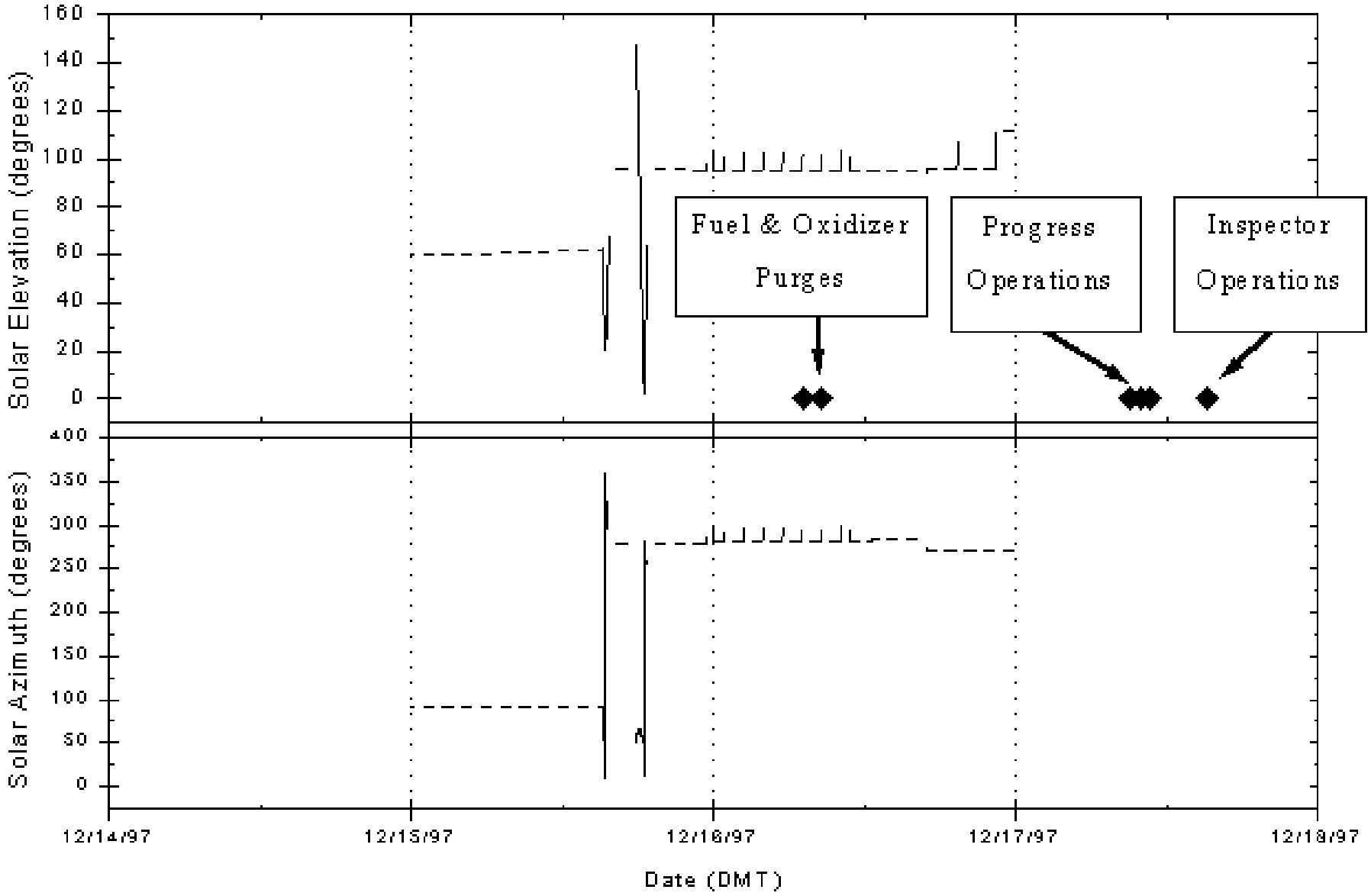


AZTek
AZ TECHNOLOGY

OPM/Mir Attitude Data for May 3, 1997



OPM/Mir Solar Attitudes/Events - 12/15 to 12/17



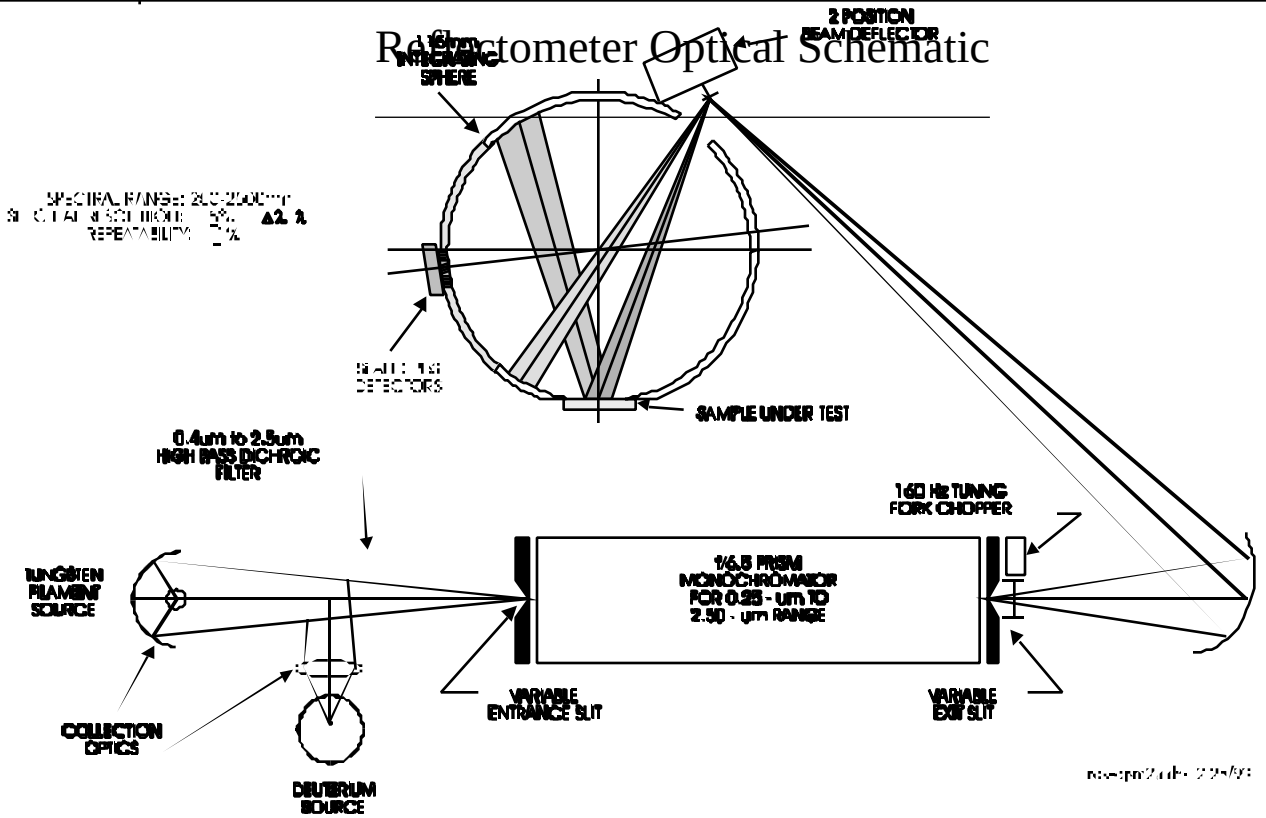
OPM Reflectometer

- Measures spectral total hemispherical reflectance from 250 nm to 2500 nm. Solar absorptance is calculated from spectral data.
- Absolute-type measurement using integrating sphere.
- Prism monochromator with selectable slits provides wavelength range and spectral resolution.
- Proven space design used on the LDEF Thermal Control Surfaces Experiment (TCSE) and improved on AZ Technology's commercial instrument program.
- Performance specifications:
  - 100 measurement points over spectral range
  - Spectral resolution: 5% of wavelength or better
  - Accuracy: + 3%
  - Repeatability: + 1%

AZ TECHNOLOGY

OPTICAL PROPERTIES MONITOR (OPM)
SEE Flight Experiments Workshop
June 24, 1998

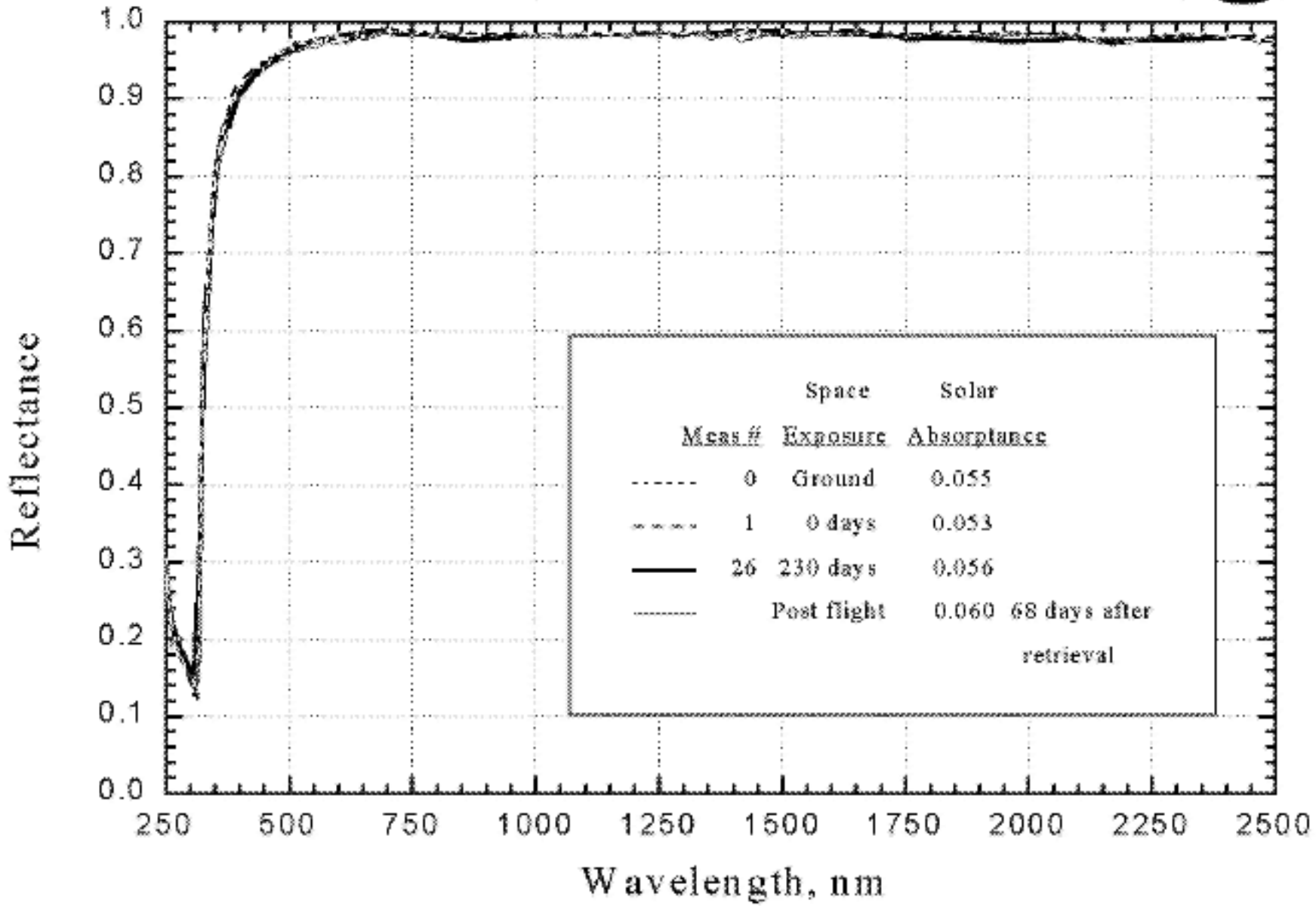
Reflectometer Optical Schematic



AZ Tek
AZ TECHNOLOGY

OPM Reflectometer Flight Data

Optical Solar Reflector

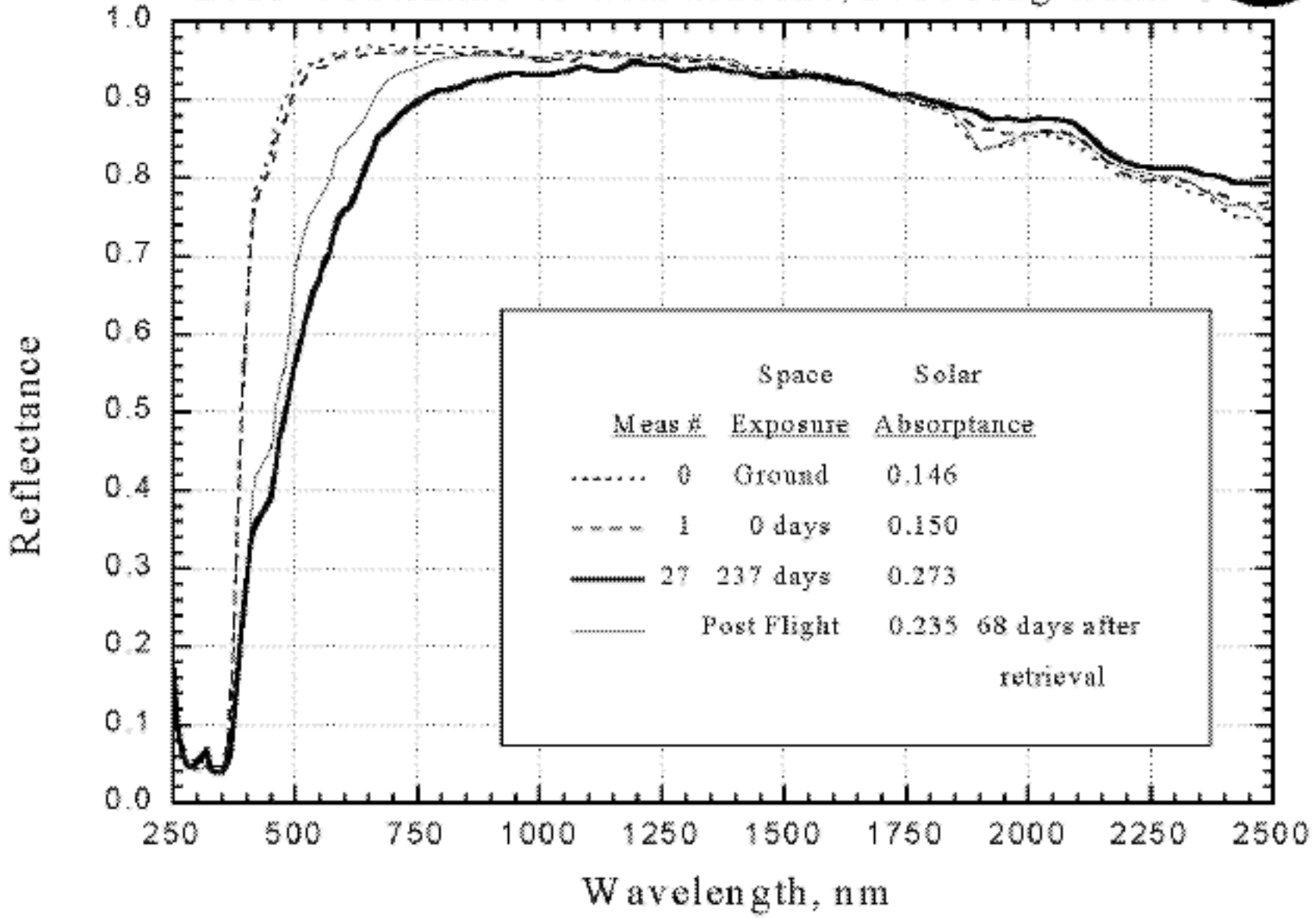


CR05

AZTek
AZ TECHNOLOGY

OPM Reflectometer Flight Data

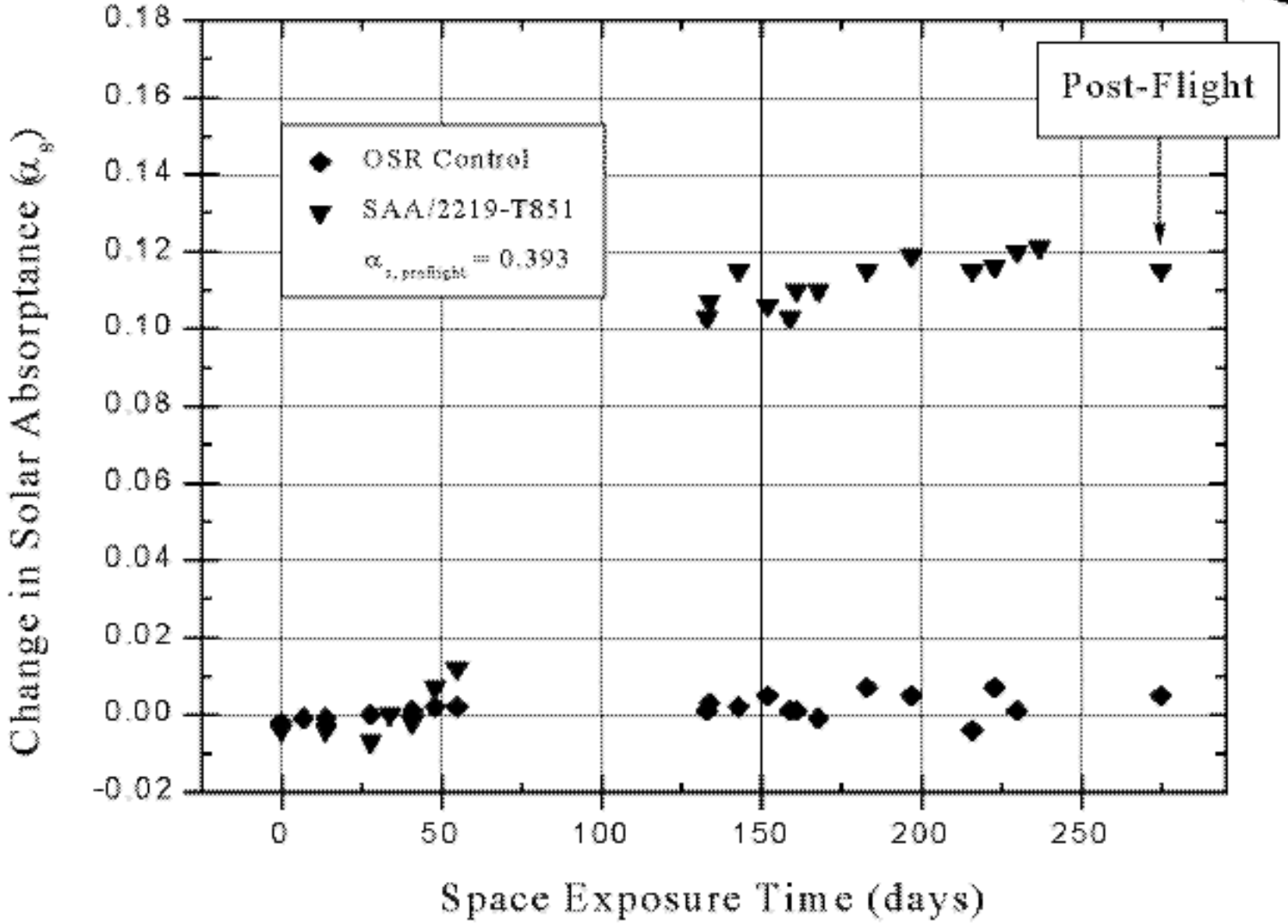
Z93P Contaminated with Silicone, 2000 Angstroms



CR19

AZ Tek
AZ TECHNOLOGY

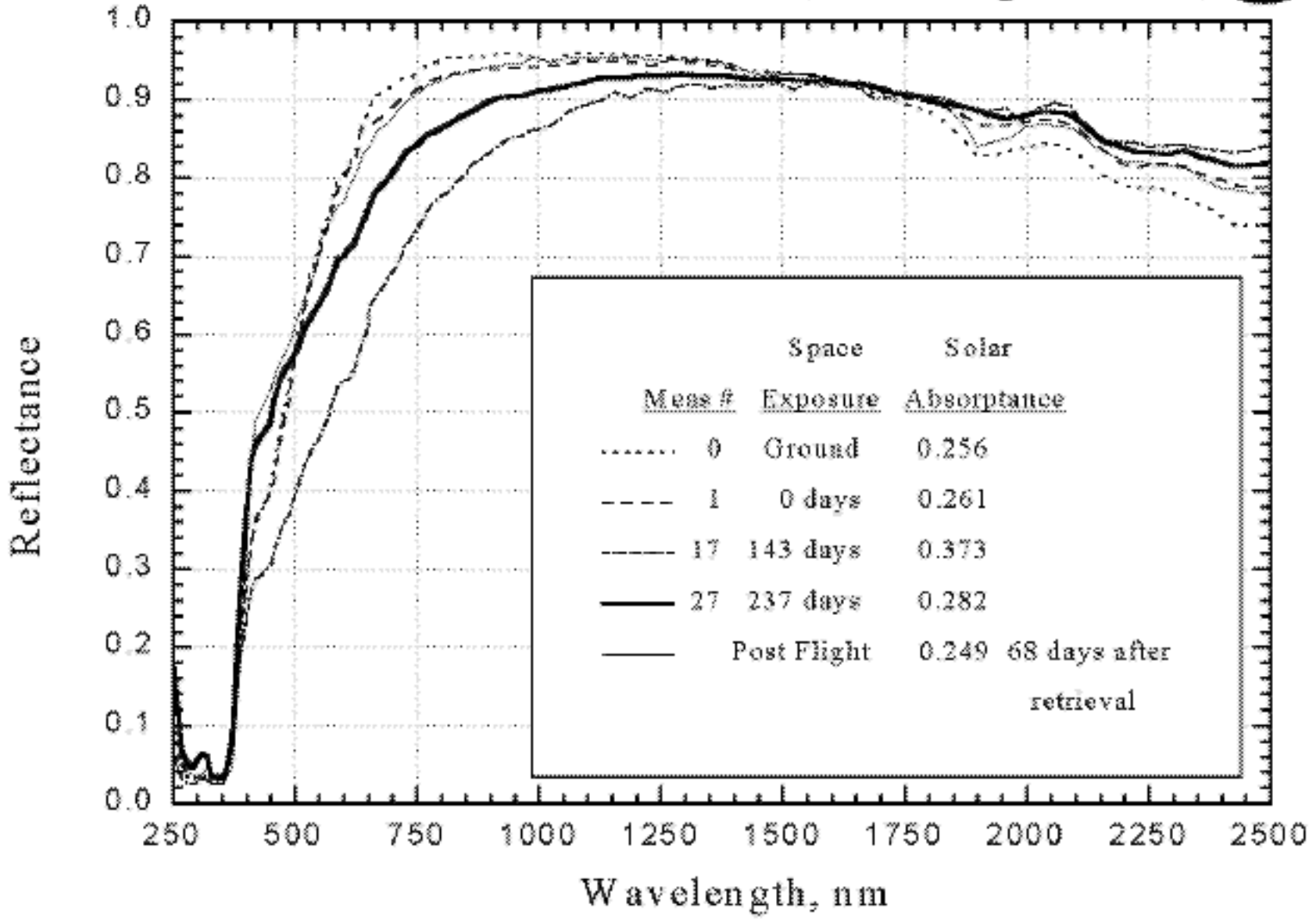
OPM Reflectometer Flight Data



AZTek
AZ TECHNOLOGY

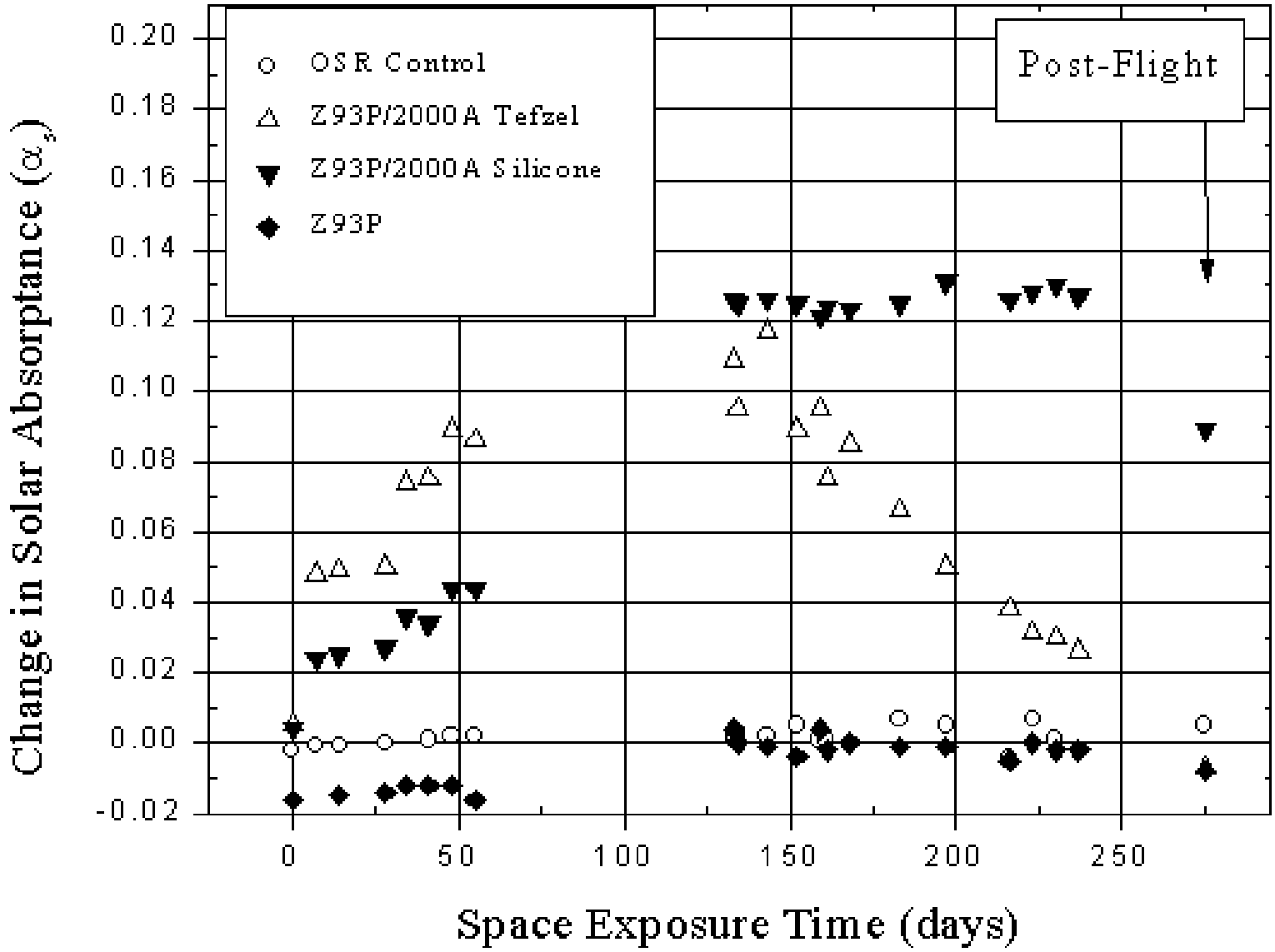
OPM Reflectometer Flight Data

Z93P Contaminated with Tefzel, 2000 Angstroms



CR20

OPM Reflectometer Flight Data



AZ TECHNOLOGY

OPTICAL PROPERTIES MONITOR (OPM)
SEE Flight Experiments Workshop
June 24, 1998

OPM Reflectometer Samples
Solar Absorptance/Emittance Change

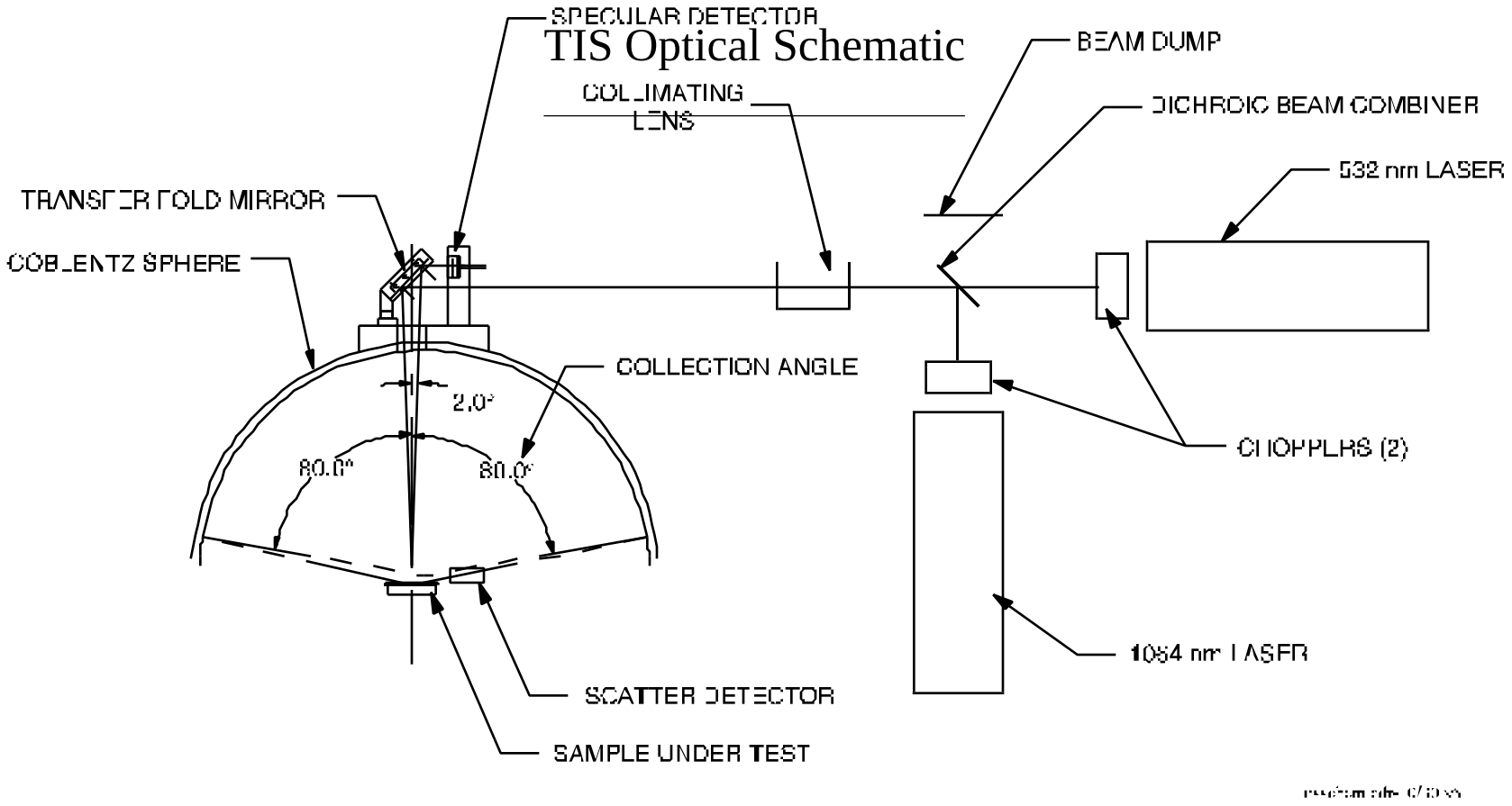
Sample Description	Supplier	ε Emittance Pre-Flight	ε Emittance Post-Flight	Δε	α_s, Solar Absorptance Pre-Flight	$\Delta \alpha_s$ 0 days (space v. grnd)	$\Delta \alpha_{s\ final}$ 237 days (space v. grnd)	$\Delta \alpha_s$ Post-Flight
Silver- COR - Triton	NASA MSFC	0.823	0.834	+0.011	0.118	0.023	0.148	0.146
TMS-800AZ, yellow	AZ Technology	0.872	0.868	-0.004	0.352	-0.008	-0.010	0.011
ESD white	AZ Technology	0.912	0.905	-0.007	0.244	0.011	n/a	n/a
Low alpha white	AZ Technology	0.903	0.898	-0.005	0.088	0.007	0.011	0.002
Optical Solar Reflector	AZ Tech/Carl Maag	0.758	0.767	+0.009	0.055	-0.002	0.001	0.005
AZ-93 over MLP-300 primer	AZ Technology	0.906	0.904	-0.002	0.160	0.001	0.005	0.006
AZ-93 w/ Teflon overcoat	NASA MSFC	0.902	0.892	-0.01	0.171	-0.002	0.096	0.063
TP-co-2, ZnO silicate & glass base	RSC Energia	0.918	0.907	-0.011	0.161	-0.004	-0.001	0.001
TP-co-12, ZnO silicate & glass base	RSC Energia	0.914	0.906	-0.008	0.148	0.000	0.005	0.002
Chromic Acid 6061 Al	Boeing (Huntsville)	0.463	0.463	-0	0.361	-0.003	0.051	0.057
Boric-Sulfuric Anodized 6061 Al	Boeing (Huntsville)	0.569	0.564	-0.005	0.360	-0.002	0.071	0.052
Chem film 1A on 2219 Al	Boeing(Canoga Prk)	0.064	0.058	-0.006	0.461	0.004	0.074	0.062
Z-93CLM55 White coating	IIT Research Inst	0.909	0.901	-0.008	0.126	-0.002	0.011	0.004
Sulfuric Acid Anodized 7075-T7351	Boeing (Hunt. Bch)	0.869	0.877	+0.008	0.424	-0.004	0.053	0.053
Sulfuric Acid Anodized 2219-T851	Boeing (Hunt. Bch)	0.820	0.831	+0.011	0.393	-0.004	0.121	0.115
Z-93P White coating	Boeing (Hunt. Bch)	0.901	0.893	-0.008	0.163	-0.016	-0.002	-0.008
Z-93P w/500A silicone	Boeing (Hunt. Bch)	0.899	0.895	-0.004	0.154	-0.005	0.052	0.040
Z-93P w/500A Tefzel	Boeing (Hunt. Bch)	0.899	0.896	-0.003	0.188	-0.004	0.003	-0.008
Z93P w/2000A silicone	Boeing (Hunt. Bch)	0.895	0.893	-0.002	0.146	0.004	0.127	0.089
Z-93P w/2000A Tefzel	Boeing (Hunt. Bch)	0.899	0.893	-0.006	0.256	0.005	0.026	-0.007

Total Integrated Scatter (TIS) Instrument

- Measures total integrated scatter of test materials.
  - Two laser wavelengths, 532 nm and 1064 nm
  - Scatter collection angle is 2.5 to 80 degrees from specular
- TIS instrument design is based on laboratory instruments.
- TIS performance is comparable to laboratory systems.

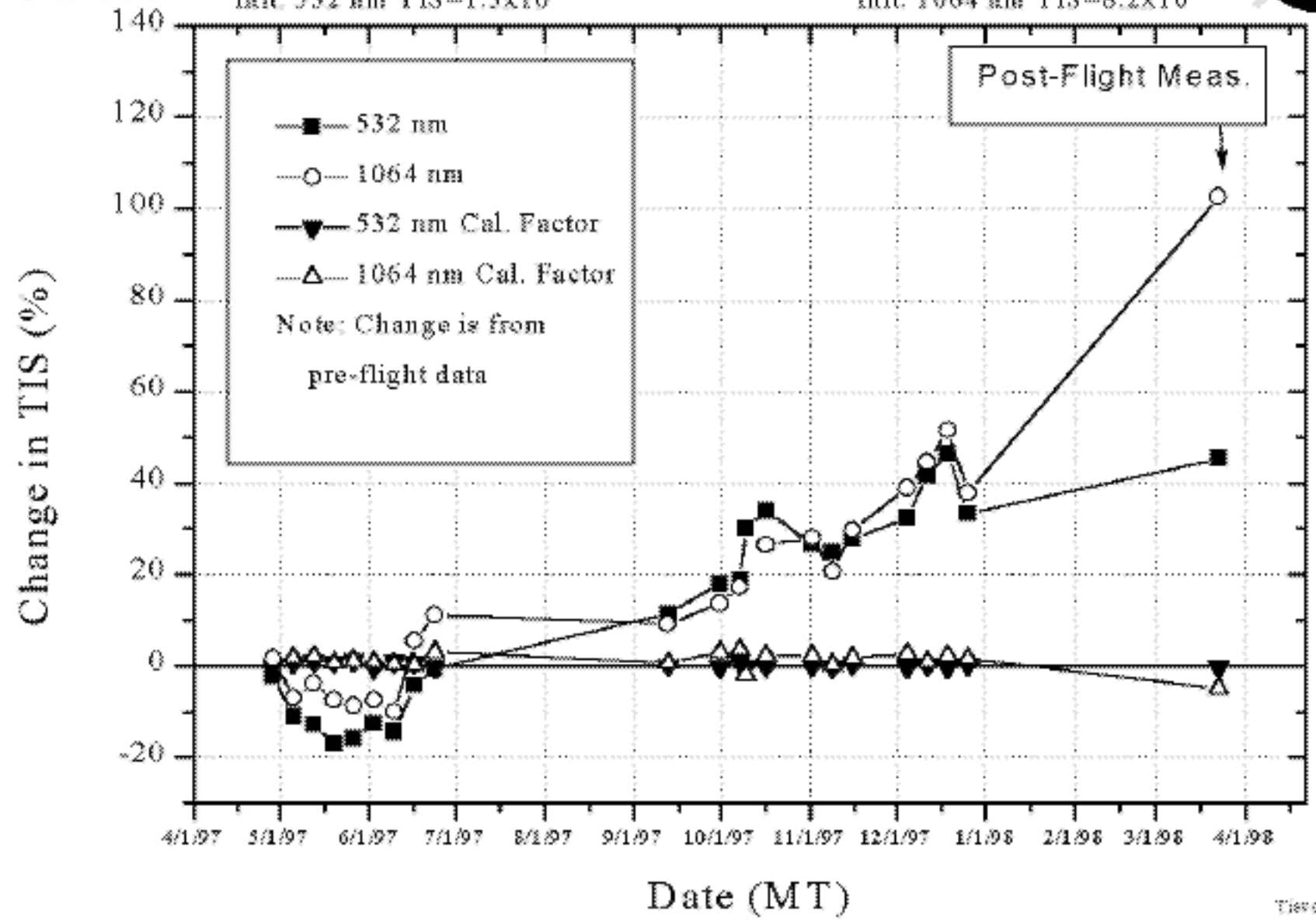
AZ TECHNOLOGY

OPTICAL PROPERTIES MONITOR (OPM)
SEE Flight Experiments Workshop
June 24, 1998



OPM Flight Total Integrated Scatter Data

AlMgF Mirror



AZ TECHNOLOGY

OPTICAL PROPERTIES MONITOR (OPM)
SEE Flight Experiments Workshop
June 24, 1998

Preliminary Results Summary

- Less than 200Å of permanent molecular contamination was measured by the TQCMs.
  - Many transient events were observed by the TQCM's.
  - Most accumulated mass from these events re-evaporated.
  - The OPM samples (and TQCMs) field-of-view was of 6-11 year old modules.
  - There was minimal solar UV for most of the mission.
  - Mass accumulation rate is still above ISS requirement.

- No significant optical contamination effects were measured by the OPM reflectometer (250-2500nm).

- Sides of OPM show significant degradation with distinct shadowing from OPM handrails.

- Some flight samples were very stable for the OPM mission.

- The OPM reflectometer measured significant exposure effects on some flight samples.

- Some post-flight recovery (bleaching) of environment effects have been measured on many samples verifying the need for in-space optical measurements.

- The TIS instrument measured significant changes in scatter on mirror samples.

Summary

- The OPM performed well on the mission to Mir and demonstrated its capability to measure the in-space behavior of materials and monitor selected components of the exposure environment.

- The processed in-flight OPM data has already provided the ISS community with unique and valuable data on the performance of materials in the Mir space environment. Subsequent analysis of test materials and OPM external surfaces will provide additional insight into material environmental effects around a space station.

- The ISS materials and contamination community has recommended that the OPM be refurbished and reflown on ISS as soon as possible to provide this unique capability for early ISS activities.

- Material analyses of the test samples and the other OPM surfaces is continuing.

- For additional information
  - http://www.azhsv.com
  - http://see.msfc.nasa.gov/see/see.html